SECTION 9

FAMILY-LEVEL ICHTHYOPLANKTON INDEX METHODS[1]

9.1 Introduction

9.1.1 The early life history stages of fishes are recognized as the most sensitive and vulnerable life stage (Blaxter, 1974; Moser et al., 1984; Weis and Weis, 1989). The ability to document status and trends without identifying most taxa to species has caused some doubt as to the relevance of resolution abilities of using ichthyoplankton in bioassessment studies.

9.1.2 Although there are some reluctance to conduct further ichthyoplankton studies detailed enough to answer water quality questions, investigators have continued to gather important and useful knowledge on the early life stages of fishes. A recent explosion in the amount and types of literature includes documentation of nursery habitats (Goodyear et al., 1982), ecological early life history notes (Simon and Wallus, 1989; Wallus, 1986; Wallus and Buchanan, 1989), taxonomic studies of regionally important systems (Auer, 1982; Holland and Huston, 1983; Simon, 1990; Wallus et al., 1989), toxicological studies using early life history stages (Norberg and Mount, 1983; Birge et al., 1985; Simon, 1988), and effects of environmental pollution (Weis and Weis, 1989).

9.1.3 The purpose of the family-level ichthyoplankton index methods is to present guidelines and an index for the use of ichthyoplankton in bioassessment studies and for determining water quality. The use of a qualitative collection method with a family-level taxonomic approach will facilitate use without complicating logistics and level of effort. The family-level index is based on three components: taxonomy, reproductive guild, and abundance and deformity. Water quality managers, in addition, could use this information to document reproduction, nursery habitats, and backwater habitats not conventionally surveyed during routine adult fish or marcoinvertebrate collection. The format and structure of the ichthyoplankton index (I^2) is modeled after the index of biotic integrity (IBI) using a family-level approach. Since the proponents of the IBI recommend against use of larval and juvenile stages in they analyses (Angermeier and Karr 1986; Karr et al., 1986), the I^2 can be an additional use of data collected during a routine adult sampling event. Current knowledge on the identification of most freshwater faunas are limited, however, a listing of appropriate references is included in Table 1.

9.1.4 The loss of habitat through the accumulation of toxic chemicals in the sediment, reduction of dissolved oxygen, and increase in siltation, is perhaps the greatest obstacle to the protection of environmental quality the environmentalist must face. Degradation by conventional nonpoint sources of pollution have yet to be addressed, rather efforts have concentrated on point sources. USEPA has spent two decades quantifying the effluent quality of point source dischargers. With toxicity endpoints established in industrial

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[1]Adapted from Simon (1989).

TABLE 1. TAXONOMIC LITERATURE USEFUL FOR IDENTIFICATION OF LARVAL AND EARLY JUVENILE NORTH AMERICAN FRESHWATER FISH (ALSO SEE SECTION 12, BIBLIOGRAPHY, SUBSECTION 12.4.2 LARVAL AND IMMATURE FISHES)

Author(s) and Publication Date	Region
Auer, 1982	Great Lakes Basin, emphasis Lake Michigan
Colton and Marak, 1969	Northeast Coast, Black Island to Cape Sable
Drewry, 1979	Great Lakes Region
Elliott and Jimanez, 1981	Beverly Salem Harbor Area, Massachusetts
Fish, 1932	Lake Erie
Fritzsche, 1978	Mid-Atlantic Bight (Chaetodontidae through Ophidiidae)
Hardy, 1978a	Mid-Atlantic Bight (Aphredoderidae through Rachycentridae)
Hardy, 1978b	Mid-Atlantic Bight (Anguillidae throuygh Syngnathidae)
Holland and Huston, 1983	Upper Mississippi River
Hogue et al., 1976	Tennessee River
Johnson, 1978	Mid-Atlantic Bight (Carangidae through Ephippidae)
Jones et al., 1987	Mid-Atlantic Bight (Acipenseridae through Ictaluridae)
Lippson and Moran, 1974	Potomac River Estuary
Mansueti and Hardy, 1967	Chesapeake Bay Region
Martin and Drewry, 1978	Mid-Atlantic Bight (Stromateidae through Ogcocephalidae)
May and Gasaway, 1967	Oklahoma, Canton Reservoir
McGowen, 1984	South Carolina, Robinson Impoundment
McGowen, 1989	North Carolina Piedmont Impoundment

TABLE 1. TAXONOMIC LITERATURE USEFUL FOR IDENTIFICATION OF LARVAL AND EARLY JUVENILE NORTH AMERICAN FRESHWATER FISH (CONTINUED) (ALSO SEE SECTION 12, BIBLIOGRAPHY, SUBSECTION 12.4.2 LARVAL AND IMMATURE FISHES)

Author(s) and Publication Date	Region
Scotton et al., 1973	Delaware Bay Region
Snyder, 1981	Upper Colorado River System, Colorado
Sturm, 1988	Alaska
Taber, 1969	Oklahoma and Texas, Lake Texoma
Wallus et al., 1989	Ohio River basin, emphasis on Tennessee and Cumberland drainages
Wang, 1981	Sacramento-San Joaquin Estuary and Moss Landing Harbor Elkhorn Slough, CA
Wang and Kernehan, 1979	Delaware Estuary

and municipal permits, attention must be focused on instream degradation through chronic exposure to ambient residents.

9.1.5 The effort to combine a community approach for addressing these issues has been accomplished in adult fish (Karr, 1981; Karr et al., 1986), macroinvertebrates (Plafkin et al., 1989), and now with ichthyoplankton here in this section. Karr and colleagues have described in detail the rationale for this overall approach. The reader is referred to their documentation for further reading rather than repeating their rationale (Karr et al. 1986). In this Section details are provided for the scoring and information of an ichthyoplankton index using a community based approach.

9.1.6 The need to look at various trophic levels in the analysis of environmental degradation, through biological integrity, is difficult to explore in insects due to taxonomic and limited ecological information. In fishes, ontogenetic shifts during development not only is apparent in morphological changes (Fuiman and Corazza, 1979), but also niche shifts (George and Hadley, 1979; Brandt, 1986). The early life stages of fishes often documents the use of habitats by endangered or rare species when the adults can frequently not be found. The protection of these important habitats require further consideration in protection of species diversity.

9.1.7 The I^2 is an additional tool which can be concurrently conducted using IBI type techniques, and the method may prove useful in both lotic and lentic habitats. The difficulty in assessing lentic habitats is the inability of species to recolonize closed systems. Field evaluations of both habitat types are necessary prior to further evaluation of the method.

9.1.8 The implications of data quality depends on the calibration of the metrics and collection of a representative sample (Davis and Simon, 1988). Every effort should be made to incorporate quality assurance checks into standard operating procedures and data analysis. Further refinement of techniques and interpretation will become apparent with increases in knowledge of a balance aquatic environment especially as recruitment success and early life history states of fishes are influenced.

9.1.9 Interpretation of the I^2 follows that previously established by the IBI. The use of a three tiered scoring criteria, 5, 3, and 1, are assigned to each metric depending on whether it approximates, deviates somewhat from, or deviates strongly from the value expected at the least impacted ecoregion reference site. The sampling site is then assigned to one of six quality classes based on the sum total of the eleven metric ratings. The highest score, 55, indicates a site without perturbation and deviations decline proportionally. The qualitative ratings and descriptions of Karr (1981) range from excellent to very poor (Table 2). These similar integrity classes and attributes have been appropriately scaled for the I^2 bases on those of Karr et al. (1986).

9.1.10 Finally, although the level of discernment of taxa to a species level would be highly desired, the taxonomic literature is unable to support this level currently. The family level of discernment will reduce confusion among novices using the techniques, provided a high level of reproducability, and

TABLE 2. TOTAL ICHTHYOPLANKTON INDEX (I^2) SCORES, INTEGRITY CLASSES, AND ATTRIBUTES (MODIFIED FROM KARR, 1981)

Total I^2 Score (Sum Of 11 Metrics)	Integrity Class	Attributes
53-55	Excellent	Comparable to the best situations without human disturbance; all regionally expected taxa for habitat, stream size, and ecoregion, including the most intolerant forms; balanced guild structure and reproduction.
44-48	Good	Species richness somewhat below expectations, especially due to loss of the most intolerant forms; some taxa are present with less than optimal abundances; guild structure indicates signs of some stress.
37-40	Fair	Signs of additional deterioration include loss of intolerant forms, skewed dominance, and guild structure. Reduction in simple lithophils and in mean generation time.
26-31	Poor	Dominated by r-strategists, tolerant forms and pioneer species. Increase in guild A.1, and in deformities or teratogenic fish.
11-20	Very Poor	Few fish present, lack of successful reproduction in any guild, deformed or teratogenicity frequently observed.
	No Fish	Repeated sampling finds no fish.

subsequently data quality assurance through accuracy. As an increase in the ecological requirements and taxonomic literature become available, a more sensitive analyses will be possible. Stimulation of single species and comparative larval descriptions and species reproductive characterization should receive higher priority among researchers in the field.

9.2 Methods and Materials

9.2.1 Sampling and Requirements

9.2.1.1 The objectives of the I^2 are to provide a rapid screening method using a single collection event to determine effects of water quality on reproduction and the early life stages of fishes. Collection of a representative sample of ichthyoplankton requires a variety of gear types, and geographical, spatial and temporal considerations. The greater the stream complexity, the greater the distance needed to be sampled; e.g., a second order stream should be surveyed approximately 100 m, while a good rule of thumb is fifteen times the river width or two habitat cycles (Gammon et al., 1981; Karr et al., 1986). Reproduction by fishes occurs within a smaller habitat scale than adult species occurrence. Fishes may rely on a broader area for foraging and etching out an existence, however, only specialized "select"habitats are utilized for reproduction and serve as a nursery habitat. Because of patchy distribution of eggs and larvae a large enough area needs to be investigated to determine local use of a particular stream reach.

9.2.2 Gear Types

9.2.2.1 The more complex the environment the more numerous and sophisticated are equipment needs. The most typical equipment used for collection of larval fishes include, plankton nets; seines, dip nets, and sweep nets; light traps; and push nets and benthic sleds. Snyder (1983) provides documentation on rationale and use of most of the above equipment. Light traps can be constructed for lentic (Faber, 1981; 1982), and lotic waters (Muth and Haynes, 1984), and information on the use of the equipment can be determined from references contained therein. Push nets and benthic sleds are described by Tuberville (1979) and Burch (1983). Also, see Section 4, Sample Collection for Analysis of the Structure and Function of Fish Communities.

9.2.3 Geographical Considerations

9.2.3.1 Landscape differences have long been recognized, and methods to differentiate between various scales have been attempted using zoogeographical realms, biomes, and most recently ecoregions. The ecoregions concept is the most consistent means if evaluating community composition for a water quality based approach. Omernik (1987) defined the conterminous United States into a series of smaller discrete units. Aquatic biological characterization using this approach has been completed for adult fish and macroinvertebrates in several States including Ohio (Larsen et al., 1986; Ohio EPA, 1987), Arkansas (Bennett et al., 1987; Geise and Keith, 1988), North Carolina (Penrose and Overton, 1988), and Vermont (Langdon, 1988).

9.2.4 Spatial Considerations

9.2.4.1 Riffles of rapid flow areas are not the most likely places to encounter larval or juvenile fishes, rather the head of a pool, side margin of a channel and backwater areas are preferred. A representative larval sample should be collected from all available habitats within a stream reach. For example, a large river sample should consist of various depth fractions from the main channel, main channel border, side border and backwaters. Low flow areas will reveal higher diversity of taxa while the remaining large river species will be collected while drifting in the main channel (Simon, 1986a). These diverse areas should be pooled for an overall evaluation of the site while each component habitats, "relative value", can be quantitatively assessed for its contribution to the whole. Creeks, stream, and small rivers will require fewer areas to comprise a representative sample, however, any reduced flow or eddy area will be in need of sampling within a given location. Ideal habitats include those with submerged and emergent aquatic macrophytes, overhanging bank vegetation and roots.

9.2.5 Temporal Considerations

9.2.5.1 Numerous reports and journal articles have documented spawning temperature requirements of various faunas. In order to collect a representative sample from a particular location, familiarity with the reproductive literature and selection of appropriate sample times are necessary. For example, in the midwest the earliest spawning fishes initiate spawning under the ice, with larval emergence and hatching immediately after ice-out during late March and early April. The last species to initiate spawning are usually finished by mid-July with a majority of species spawning during June (Simon, 1986a). Ichthyoplankton and early juvenile sampling should be initiated in the midwest, no sooner than mid-June and no later than the end of September to ensure collection of a representative sample.

9.2.5.2 The use of different gear types will facilitate collection of families which are earlier spawning, e.g. percids, cottids, salmonids, and catostomids. Due to north to south temperature clines, and east to west rainfall differences, species will cue on spawning earlier in the south and west and later in the north and east for the same species. Sampling needs to be adjusted accordingly.

9.2.5.3 Equally important is diel differences in specimen collection. Numerous studies have documented significant differences between dusk and sunset, daylight, and night sampling. The general pattern is the more turbid the water body the less likely diel affects will be a problem. When one decides to sample, is not as important as it is for them to be consistent. Safety considerations and study objectives may not deem night sampling necessary. However, light trap use, set up using an automatic timing device may enable night time sampling without the inconvenience and danger. This method has successfully been used by Alabama Power on the Tallapoosa River.

9.2.5.4 Since much of the North American fauna is incompletely described (Simon, 1986b), use of the index is limited to a family approach until the taxonomic literature facilitates species specific recognition. The eleven I^2 metrics are based on three broad categories. Metrics are organized into taxonomic composition, reproductive guild, and abundance, generation time and

deformity categories. No single metric is always a reliable indicator of degradation, however, relative sensitivity is determined by region, scale, and application.

9.2.5.5 The metrics will react differentially based on the type of perturbation. For example, if contaminated sediments are suspected, the proportion of lithophils and number of sensitive families should decline depending on the magnitude of the impact, while equitability and perhaps deformity should increase.

9.2.5.6 The remainder of this section provides information, justification and rationale behind each of the I^2 metrics (Table 3). Additional refinement may be necessary to meet the objectives of the investigators study.

9.2.5.7 Taxonomic Composition. This category is useful for assessing family diversity and community richness. The current level of taxonomy requires that discussion be limited to a family level but future use of the index may make this a species specific approach. Expectations should be determined for various stream size and calibrated by equipment based on information presented in Fausch et al. (1984). Taxa diversity has been determined to be the best sole indicator of "good" water quality. Sensitive families such as percids, cottids. ictalurids, and others listed in Table 4, are useful for determining the extent of impact to sediments and nursery habitats. Finally, dominance of tolerant species increase proportionally to environmental degradation.

9.2.6 **Metric 1. Total Number of Families.** The fluctuation in number of families of an ecoregion increased with stream order. If the same order stream, in the same ecoregion, with similar habitat cycles were sampled, then reduction in numbers of families would correspond to environmental degradation. A number of investigators have determined number of taxa is the single most important metric which highly correlates with more pristine water quality (Ohio EPA, 1987; Davis and Lubin, 1989; Plafkin et al., 1989).

9.2.7 **Metric 2. Number of Sensitive Families.** Certain families of freshwater fish are sensitive to degradation, particularly as a result of reproduction requirements and early life ecology (Table 4). Families such as Percidae, Cottidae, and Salmonidae are intolerant to siltation and low dissolved oxygen. Sediment contamination due to toxins and low dissolved oxygen inhibits most benthic families (e.g., Ictaluridae). Reduction in habitat quality (e.g., channelization, thermal inputs, reservoir flooding) reduces Catostomidae, Centrarchidae, Cyprinidae, and Fundulidae. Sensitive families should be restricted to those most sensitive to low dissolved oxygen, toxic chemicals, siltation, and reduced flow. Karr et al. (1986) suggested that species sensitive to habitat degradation, especially siltation, are most likely to be identified as intolerant.

9.2.8 **Metric 3. Equitability/Dominance.** As water quality declines certain taxa tend to become increasingly abundant (Karr et al., 1986). Also, species defined as r-strategists tend to inundate the environment with early life phases (MacArthur, 1957; MacArthur and Wilson, 1967). The strategy to produce large numbers of young are indicative of "pioneer" species which are attempting to colonize perturbed areas. In habitats with least impacted

TABLE 3. METRICS USED TO ASSESS ICHTHYOPLANKTON COMMUNITIES FROM FRESHWATERS OF NORTH AMERICA

Category	Metric	Scoring Criteria 5	3	1
Taxonomic Composition				
1.	Total Number of Families	Drainage Size and Ecoregion Dependent		
2.	Number of Sensitive Families	Drainage Size and Ecoregion Dependent		
3.	Equitability/Dominance	>0.8-1.0	>0.6-0.8	0-< 0.6
4.	Family Biotic Index	0-4.5	>4.5-7.5	>7.5-10
Reproductive Guild				
5.	% Non-guarding Guild A.1 and A.2	Drainage Size and Ecoregion Dependent		
6.	% Guarding Guild B.1 and B.2	Drainage Size and Ecoregion Dependent		
7.	% Bearers Guild C.1 and C.2	Drainage Size and Ecoregion Dependent		
8.	% Simple Lithophil Mode Reprod.	Drainage Size and Ecoregion Dependent		
Abundance, Generation Time, and Deformity				
9.	Catch per Unit Effort	Drainage Size and Ecoregion Dependent		
10.	Mean Generation Time	Drainage Size and Ecoregion Dependent		
11.	% Deformity or Teratogenicity	<1%	>2-5%	>5%

TABLE 4. SENSITIVITIES, MEAN GENERATION TIME, AND REPRODUCTIVE GUILD CHARACTERISTICS OF 34 NORTH AMERICAN FRESHWATER FISH FAMILIES

Family	Sensitivity	Generation Time[1]	FBI[2]	Reproductive Guild
Petromyzontidae	Moderate	Short/Moderate	3	A.1
Acipensideridae	Moderate	Long	2	A.1
Polyodontidae	Intolerant	Long	2	A.1
Lepisosteidae	Tolerant	Moderate	4	A.1
Amiidae	Tolerant	Moderate	8	B.2
Anguillidae	-	Moderate	3	A.1
Clupeidae	Moderate	Short	6	A.1
Hiodontidae	Intolerant	Short/Moderate	4	A.1
Salmonidae	Intolerant	Moderate/Long	1	A.1
Osmeridae	Moderate	Short	5	A.1
Umbridae	Tolerant	Short	9	A.1
Esocidae	Moderate	Moderate	6	A.1
Characidae	Moderate	Short	5	A.1
Cyprinidae	Moderate	Short	6	A.1, A.2, B.1, B.2
Catostomidae	Intolerant	Moderate	4	A.1, A.2
Cobitidae	Intolerant	Short	4	A.1
Ictaluridae	Intolerant	Moderate	3	B.2
Claridae	Tolerant	Moderate	10	A.2
Amblyopsidae	Intolerant	Short	4	C.1
Aphredoderidae	Tolerant	Short	8	C.1
Percopsidae	Moderate	Short	7	A.1
Gadidae	Moderately	Moderate/Long	5	A.1
Oryzintidae	Tolerant	Short	7	C.2
Cyprinodontidae	Intolerant	Short	2	A.1, A.2
Fundulidae	Intolerant	Short	5	A.1, A.2
Poeciliidae	Tolerant	Short	8	C.2
Atherinidae	Moderate	Short	3	A.1
Gasterosteidae	Tolerant	Short	9	B.2
Moronidae	Intolerant	Moderate	6	A.1
Centrarchidae	Intolerant	Moderate	5	B.1
Elassomatidae	Intolerant	Short	3	B.2
Percidae	Intolerant	Short	0	A.1, A.2, B.1, B.2
Sciaenidae	Moderate	Moderate	4	A.1
Cichlidae	Tolerant	Moderate	7	B.2
Cottidae	Intolerant	Short	0	B.2

[1]Classified as short, moderate, and long appropriately scored 1, 3, 5, respectively. A community mean is calculated by summing scores and dividing by total number of families.

[2]Scored from 0 to 10. The higher the score the greater the tolerance to organic enrichment. FBI = Family Biotic Index.

environments, taxa tend to be equally distributed and more moderately abundant. The Shannon diversity index and the measure of evenness are used to determine quality environments which have balanced communities. These single unit measures are not adequate in themselves to extrapolate excellent quality, but they do determine increasing levels of disturbance. Equitability (Lloyd and Ghelardi, 1964) is determined by comparing the number of families in the sample with the expected number of families from a community which conforms to the MacArthur broken stick model. MacArthurs' broken stick model is normally higher than real diversity and is the ecologically maximum diversity attainable (Washington, 1984). Equitability is measured by:

$$e = s'/s$$

where:

s = number of taxa in the sample,
s'= the tabulated value based on the Shannon diversity index

The diversity index is the $\bar{d}$ formulation of Lloyd, Zar, and Karr (1968). The diversity index is:

$$\bar{d} = C/N \ (N \log_{10} N - E \ n_i \log_{10} n_i)$$

where:

C = 3.321928,
N = total number of individuals in the ith taxa,
n_i = total number of individuals in the ith taxa.

An example calculation and reproduction of Lloyd and Ghelardi's (1964) table are included in Table 5 and are taken from USEPA (1973, 1990). As a side note, if solely ichthyoplankton data sets are to be used excluding juveniles, the following families need to be omitted: Clupeodae. Scianenidae, and Osmeridae.

9.2.9 **Metric 4. Family Biotic Index.** Discussions with other ichthyoplanktologists studying the ecological and taxonomic early life stages of fishes suggest varying degrees of sensitivity exists between organic pollution and perturbations such as sediment, degradation, siltation, low dissolved oxygen, toxic chemicals, and flow reduction (Table 4). The calculation of the Family Biotic Index (FBI) is modeled after Hilsenhoff's (1988) modified biotic index which summarizes tolerances to organic pollution. Tolerance values range between 0 to 10 for families and increase as water quality decreases. The formula for calculating the Family Biotic Index is:

$$FBI = e \ x_i t_i / N$$

where:

x_i = total number of individuals within a taxon,
t_i = tolerance value of a taxon,
N = total number of organisms in the sample.

TABLE 5. THE DIVERSITY OF SPECIES, $\bar{d}$, CHARACTERISTIC OF MACARTHUR'S MODEL FOR VARIOUS NUMBERS OF HYPOTHETICAL SPECIES, S' (From Lloyd and Ghelardi, 1964)

s'	$\bar{d}$	s'	$\bar{d}$	s'	$\bar{d}$	s'	$\bar{d}$
1	0.0000	51	5.0941	102	6.0792	205	7.0783
2	0.8113	52	5.1215	104	6.1069	210	7.1128
3	1.2997	53	5.1485	106	6.1341	215	7.1466
4	1.6556	54	5.1749	108	6.1608	220	7.1796
5	1.9374	55	5.2009	110	6.1870	225	7.2118
6	2.1712	56	5.2264	112	6.2128	230	7.2434
7	2.3714	57	5.2515	114	6.2380	235	7.2743
8	2.5465	58	5.2761	116	6.2629	240	7.3045
9	2.7022	59	5.3004	118	6.2873	245	7.3341
10	2.8425	60	5.3242	120	6.3113	250	7.3631
11	2.9701	61	5.3476	122	6.3350	255	7.3915
12	3.0872	62	5.3707	124	6.3582	260	7.4194
13	3.1954	63	5.3934	126	6.3811	265	7.4468
14	3.2960	64	5.4157	128	6.4036	270	7.4736
15	3.3899	65	5.4378	130	6.4258	275	7.5000
16	3.4780	66	5.4594	132	6.4476	280	7.5259
17	3.5611	67	5.4808	134	6.4691	285	7.5513
18	3.6395	68	5.5018	136	6.4903	290	7.5763
19	3.7139	69	5.5226	138	6.5112	295	7.6008
20	3.7846	70	5.5430	140	6.5318	300	7.6250
21	3.8520	71	5.5632	142	6.5521	310	7.6721
22	3.9163	72	5.5830	144	6.5721	320	7.7177
23	3.9779	73	5.6027	146	6.5919	330	7.7620
24	4.0369	74	5.6220	148	6.6114	340	7.8049
25	4.0937	75	5.6411	150	6.6306	350	7.8465
26	4.1482	76	5.6599	152	6.6495	360	7.8870
27	4.2008	77	5.6785	154	6.6683	370	7.9264
28	4.2515	78	5.6969	156	6.6867	380	7.9648
29	4.3004	79	5.7150	158	6.7050	390	8.0022
30	4.3478	80	5.7329	160	6.7230	400	8.0386
31	4.3936	81	5.7506	162	6.7408	410	8.0741
32	4.4381	82	5.7681	164	6.7584	420	8.1087
33	4.4812	83	5.7853	166	6.7757	430	8.1426
34	4.5230	84	5.8024	168	6.7929	440	8.1757
35	4.5637	85	5.8192	170	6.8099	450	8.2080
36	4.6032	86	5.8359	172	6.8266	460	8.2396
37	4.6417	87	5.8524	174	6.8432	470	8.2706
38	4.6792	88	5.8687	176	6.8596	480	8.3009
39	4.7157	89	5.8848	178	6.8758	490	8.3305
40	4.7513	90	5.9007	180	6.8918	500	8.3596
41	4.7861	91	5.9164	182	6.9076	550	8.4968
42	4.8200	92	5.9320	184	6.9233	600	8.6220
43	4.8532	93	5.9474	186	6.9388	650	8.7373
44	4.8856	94	5.9627	188	6.9541	700	8.8440
45	4.9173	95	5.9778	190	6.9693	750	8.9434
46	4.9483	96	5.9927	192	6.9843	800	9.0363
47	4.9787	97	6.0075	194	6.9992	850	9.1236
48	5.0084	98	6.0221	196	7.0139	900	9.2060
49	5.0375	99	6.0366	198	7.0284	950	9.2839
50	5.0661	100	6.0510	200	7.0429	1000	9.3578

Number of individuals in each taxa (n_i)	$n_i \log_{10} n_i$*
41	66.1241
5	3.4949
18	22.5949
3	1.4314
1	.0000
22	29.5333
1	.0000
2	.6021
12	12.9502
4	2.4082
Total 109	139.1391

Total number of taxa. n = 10
Total number of individuals. N = 109

$N \log_{10} N$ = 222.0795 (from Table 5)
$\sum n_i \log_{10} n_i$ = 139.1391

$$= \frac{3.321928}{109} (222.0795 - 139.1391)$$

= 0.030476 X 82.9404
= 2.5

*From Table 5, in Macroinvertebrates, USEPA (1973) or Table 23, Section 7, Data Evaluation, USEPA (1990).

9.2.10 **Reproductive Guild.** Reproductive requirements of fishes coupled with early life history strategies enable a diversification of the ways habitats are used. Balon (1975, 1981) divided reproductive modes of fishes in order of evolutionary trends. Species are divided into nonguarders (guild A), guarders (guild B), and bearers (guild C). The increase in evolutionary sophistication from guilds A to C, generally conforms to levels of increased diversification and reduction in niche overlap in complex environments (Table 6). Guild dynamics are determined by three metrics in this category. The destruction of diverse habitats not only reduce utilization of these habitats for reproduction by adults, but also destroys nursery habitats for larval and juvenile phases.

9.2.11 **Metric 5. Proportion of Non-guarding Guild A.1 and A.2.** The nonguarding guild includes mostly r-stragegists which provide little parental investment into each egg, usually possess early reproduction, small body size, many small offspring, single production, and exhibit a type III mortality (MacArthur, 1957; MacArthur and Wilson, 1967). Balon (1975) described the nonguarding guild as broadcast spawners, usually without much developmental specialization, and although may construct some nests always abandons them post-reproduction. These species are often "pioneer" species and frequently are dominant only in stressed and dominant only in stressed areas which are periodically disturbed.

9.2.12 **Metric 6. Proportion of Guarding Guild B.1 and B.2.** The guarding guild typically include k-strategists as defined by MarArthur (1957) and MacArthur and Wilson (1967). This strategy favors slower development, greater competitive ability, delayed reproduction, larger body size, repeated reproduction, fewer larger progeny, and exhibits types I and II mortality. The guarding guild (Balon, 1975) is a solely ethological aspects of guild with profound ecomorphological consequences. Better protected from enemies, guarded eggs need not be numerous to assure survival of the species. As a consequence, eggs can be larger and result in more viable offspring with less food specialization. Spawning sites with low oxygen content can be used because the guarding parents clean the eggs and produce a flow of water around them by fin-fanning and oral ventilation. Fishes that do not build complicated structures, nests, but that deposit their eggs on top of a selected object, are also included in this section. The evolutionary progression has been from (1) an exclusively parental male, (2) shared parental care by the male and female, to (3) a division of roles with the female as the direct parent and the male as the guardian to (4) polygyny (Barlow, 1974).

9.2.13 **Metric 7. Proportion of Bearers Guild C.1 and C.2.** This group is divided into external and internal brooders (Balon, 1975). External brooders carry their developing eggs on the surface of their bodies or in externally filled body cavities or special organs. These include transfer, forehead, mouth, gill-chamber. skin and pouch brooders. Internal brooders have eggs fertilized internally before they are expelled from the body cavity. Special organs are developed to facilitate sperm transfer. Mating does not necessarily coincide with fertilization. After fertilization eggs can be expelled and incubated externally or retained in the body cavity of the

TABLE 6. CLASSIFICATION OF REPRODUCTION STYLES FOR FISHES IN ORDER OF EVOLUTIONARY TRENDS (FROM BALON, 1981)

	Ethological Section	A. Nonguarders
	Ecological Group	A.1. Open Substratum Spawners
Guild		Selected key features of early ontogeny
A.1.1	Pelagic spawners (pelagophils)	Numerous buoyant eggs, none or poorly developed embryonic respiratory organs, little pigment, no photophobia
A.1.2	Rock and gravel spawners with pelagic larvae (lithopelagophils)	Adhesive chorion at first, some eggs soon buoyant, after hatching free embryos pelagic by positive buoyancy or active movement, no photophobia, limited embryonic respiratory structures*
A.1.3	Rock and gravel spawners with benthic larvae (lithophils)	Early hatched embryo photophobic, hide under stones, moderately developed embryonic respiratory structures, pigment appears late
A.1.4	Nonobligatory plant spawners (phytolithophils)	Adhesive eggs on submerged items, late hatching, cement glands in free embryos, photophobic, moderately develop respiratory structures
A.1.5	Obligatory plant spawners (phytophils)	Adhesive egg envelope sticks to submerged live or dead plants, late hatching, cement glands, not photophobic, extremely will developed embryonic respiratory structures
A.1.6	Sand spawners (psammophils)	Adhesive eggs in running water on sand or fine roots over sand, free embryos without cement glands, phototropic, freely developed respiratory structures, large pectorals, large neuromast rods (cupulae)

*See the final amendment in Balon (1981), page 389.

TABLE 6. CLASSIFICATION OF REPRODUCTION STYLES FOR FISHES IN ORDER OF EVOLUTIONARY TRENDS (FROM BALON, 1981) (CONTINUED)

	Ethological Section	A. Nonguarders
	Ecological Group	A.2. Brood hiders
Guild		Selected key features of early ontogeny
A.1.7	Terrestrial spawners (aerophils)	Small adhesive eggs scattered out of water in damp sod, not photophobic, moderately developed respiratory structures
A.2.1	Beach spawners (aeropsammophils)	Spawning above the water line of high tides, zygotes in damp sand hatch upon vibration of waves, pelagic afterward
A.2.2	Annual fishes (xerophils)	In cleavage phase blastomeres disperse and rest in 1st facultative diapause, two more resting intervals obligate--eggs and embryos capable of survival for many months in dry mud
A.2.3	Rock and gravel spawners (lithophils)	Zygotes buried in gravel depressions called redds or in rock interstices, large and dense yolk, extensive respiratory plexuses for exogenous and carotenoids for endogenous respiration, early hatched free embryos photophobic, large emerging alevins
A.2.4	Cave spawners (speleophils)	A few large adhesive eggs, most hide in crevices, extensive embryonic respiratory structures, large emerging larvae
A.2.5	Spawners in live invertebrates (ostracophils)	Zygotes deposited via female's ovipositor in body cavities of mussels, crabs, ascidians or sponges(?), large dense yolk, lobes or spines and photophobia to prevent expulsion of free embryos, large embryonic respiratory plexuses and carotenoids, probable biochemical mechanism for immunosuppression

TABLE 6. CLASSIFICATION OF REPRODUCTION STYLES FOR FISHES IN ORDER OF EVOLUTIONARY TRENDS (FROM BALON, 1981) (CONTINUED)

Ethological Section	A. Nonguarders
Ecological Group	A.2. Brood hiders
Guild	Selected key features of early ontogeny
B.1.1 Pelagic spawners (pelagophils)	Nonadhesive, positively buoyant eggs, guarded at the surface of hypoxic waters, extensive embryonic respiratory structures
B.1.2 Above water spawners (aerophils)	Adhesive eggs, embryos with cement glands, male in water splashes the clutch periodically
B.1.3 Rock spawners (lithophils)	Strongly adhesive eggs, oval or cylindrical, attached at one pole by fibers in clusters, most have pelagic free embryos and larvae
B.1.4 Plant spawners (phytophils)	Adhesive eggs each to variety of aquatic plants, free embryos without cement glands swim instantly after prolonged embryonic period

Ethological Section	B. Guarders
Ecological Group	B.2 Nest spawners
Guild	Selected key features of early ontogeny
B.2.1 Froth nesters (aphrophils)	Eggs deposited in a cluster of mucous bubbles, embryos with cement glands and well developed respiratory structures
B.2.2 Miscellaneous substrate and material nester (polyphils)	Adhesive eggs attached singly or in clusters on any available substratum, dense yolk with high carotenoid contents, embryonic respiratory structures well developed, feeding of young on parental mucus common

TABLE 6. CLASSIFICATION OF REPRODUCTION STYLES FOR FISHES IN ORDER OF EVOLUTIONARY TRENDS (FROM BALON, 1981) (CONTINUED)

	Ethological Section	A. Nonguarders
	Ecological Group	B.2. Nest spawners
Guild		Selected key features of early ontogeny
B.2.3	Rock and gravel nesters (lithophils)	Eggs in spherical or elliptical envelopes always adhesive, free embryos photophobic or with cement glands swing tail-up in respiratory motions, moderate to well developed embryonic respiratory structures, many young feed first on the mucus of parents
B.2.4	Gluemaking nesters (ariadnophils)	Male guards intensively eggs deposited in nest bind together by a viscid thread spinned from a kidney secretion, eggs and embryos ventilated by male in spite of well developed respiratory structure
B.2.5	Plant material nesters (phytophils)	Adhesive eggs attached to plants, free embryos hang on plants by cement glands, respiratory structures well developed in embryos assisted by fanning parents
B.2.6	Sand nesters (psammophils)	Thick adhesive chorion with sand grains gradually washed off or bouncing buoyant eggs, free embryo leans on large pectorals, embryonic respiratory structures feebly developed
B.2.7	Hole nesters (speleophils)	At least two modes prevail in this guild: cavity roof top nesters have moderately developed embryonic respiratory structures. While bottom burrow nesters have such structures developed strongly
B.2.8	Anemone nesters (actiniariophils)	Adhesive eggs in cluster guarded at the base of sea anemone, parent coats the eggs with mucus against nematocysts, free embryo phototropic, planktonic, early juveniles select host anemone

TABLE 6. CLASSIFICATION OF REPRODUCTION STYLES FOR FISHES IN ORDER OF EVOLUTIONARY TRENDS (FROM BALON, 1981) (CONTINUED)

Ethological Section	B. Bearers
Ecological Group	C.1 External bearers
Guild	Selected key features of early ontogeny
C.1.1 Transfer brooders	Eggs carried for some time before deposition: in cupped pelvic fins, in a cluster hanging from genital pore, inside the body cavity (earlier ovoviviparous), after deposition most similar to nonguarding phytophils (A.1.4)
C.1.2 Auxiliary brooders	Adhesive eggs carried in clusters or balls on the spongy skin of ventrum, back, under pectoral fins or on a hook in the superoccipital region, or encircled within coils of female's body, embryonic respiratory circulation and pigments well developed
C.1.3 Mouth brooders	Eggs incubated in buccal cavity after internal synchronous or asynchronous, or buccal fertilization assisted by egg dummies, large spherical or oval eggs with dense yolk are rotated (churning) in the cavity or densely packed when well developed embryonic respiratory structures had to be assisted by endogenous oxydative metabolism of carotenoids, large young released
C.1.4 Gill-chamber brooders	Eggs of North American cavefishes are incubated in gill cavities
C.1.5 Pouch brooders	Eggs incubated in an external marsupium: an enlarged and everted lower lip, fin pouch, or membraneous or bony plate covered ventral pouch, well developed embryonic respiratory structures and pigments, low number of zygotes

TABLE 6. CLASSIFICATION OF REPRODUCTION STYLES FOR FISHES IN ORDER OF EVOLUTIONARY TRENDS (FROM BALON, 1981) (CONTINUED)

	Ethological Section	B. Bearers
	Ecological Group	C.2 Internal bearers
Guild		Selected key features of early ontogeny
C.2.1	Facultative internal bearers	Eggs are sometimes fertilized internally by accident via close apposition of gonopores in normally oviparous fishes, and may be retained within the female's reproductive system to complete some of the early stages of embryonic development, rarely beyond the cleavage phase: weight decreases during embryonic development (examples**: *Galeus polli*, *Rivulus marmoratus*, *Oryzias latipes*)
C.2.2	Obligate lecithotrophic livebearers	Eggs fertilized internally, incubate in the reproductive system of female until the end of embryonic phase or beyond, no maternal-embryonic nutrient transfer: as in oviparous fishes yolk is the sole source of nourishment and most of the respiratory needs; some specialization for intrauterine respiration, excretion and osmoregulation: decrease in weight during embryonic development (examples: *Torpedo ocellata*, *Poeciliopsis monaclia*, *Poecilia reticulata*, *Xenopoecilus poptae*, *Schastes marinus*)
C.2.3	Matrotrophous oophages and adelphophages	Of many eggs released from an ovary only one or at most a few embryos develop into alevins and juveniles+, feeding on other less developed yoked ova present and/or periodically ovulated (oophagy), and in more specialized forms, preying

**Note differences in the earier paper (Balon, 1975)
+Terminology as in Balon (1981).

TABLE 6. CLASSIFICATION OF REPRODUCTION STYLES FOR FISHES IN ORDER OF EVOLUTIONARY TRENDS (FROM BALON, 1981) (CONTINUED)

Ethological Section	B. Bearers	
Ecological Group	C.2 Internal bearers	
Guild		Selected key features of early ontogeny
C.2.3	Matrotrophous oophages and adelphopages (continued)	on less developed sibling embryos (adelphophagy): specialization for intrauterine respiration, secretion and osmoregulation similar to the previous guild: large gain in weight during intrauterine development (examples: *Lumma cornubica*, *Eugamphodus temus*, *Latimeria chalumnae*?)
C.2.4	Viviparous trophoderms	Internally fertilized eggs develop into embryos, alevins or juveniles whose partial or entire nutrition and gaseous exchange is supplied by the mother via secretory histotrophes ingested or absorbed by the fetus via epithelial absorptive structures (placental analogues) or a yolk sac placenta: small to moderate gain in weight during embryonic development (examples: *Galeus canis*, *Myliobatis bovina*, *Mustelus canis*, *Sphyrna tiburo*, *Zoarces viviparus*, *Ameca splendens*, *Poeciliopsis turneri*, *Heterandria formosa*, *Anableps dowi*, *Embiotoca lateralis*, *Clinus superciliosus*)

female, after which full-grown juveniles are born (Hoar, 1969; Balon, 1975, 1981).

9.2.14 **Metric 8. Proportion of Simple Lithophil Mode of Reproduction.** This metric is used by Ohio EPA (1987) as a substitute in the adult IBI for hybrids. Simple lithophils spawn where their eggs can develop in the interstices of sand, gravel, and cobble substrates without parental care. Generally, as the level of environmental degradation of simple lithophils decreases. This is important in determining impacts from chronic levels of exposure in sediments, and settling out of toxins in pools or backwater habitats.

9.2.14.1 Abundance, Generation Time, and Deformity. Impacts to individuals often are a compounding problem effecting community analyses. Reduction in numbers of individuals, lowering of community mean generation time, and increases in observed deformity and teratogenicity correspond with environmental degradation. Loss of longer-lived species which require specialized habitats (e.g., *Acipenser fulvescens* and *Atractosteus spatula*) during reproduction and nursery are increasing at an alarming rate. Mean generation time is a function of the time to first reproduction. This metric may need further research before it can be utilized since it is proposed as a community metric rather than as an individual metric as it was conceived.

9.2.15 **Metric 9. Catch per Unit Effort.** Population abundance varies with ecoregion, stream size, and gear type used. It may be expressed as the catch per unit effort, either by area, distance, or time sampled. Sites with lower biological integrity will have reduced numbers of individuals, however, rapidly flowing riffles should be excluded from comparison with pools and run habitats (see spatial considerations). Organic enrichment usually increases the number of individuals. Steedman (1988) addressed this situation by scoring catch per minute of sampling. Unusually low numbers generally indicate toxicity which is readily apparent at low levels of biological integrity.

9.2.16 **Metric 10. Mean Generation Time.** Mean generation time is the average age of parenthood, or the average age at which all offspring are born. A longer-lived k-strategists species often spend several years before reaching reproductive maturity, e.g., Salmonidae, Polyodontidae and Acipenseridae. Vulnerability of these organisms to perturbations may have significant impact to future recruitment during the larval and juvenile stages of development. Mean generation time is an average value for a family based on life strategy of representative taxa. Mean generation time is calculated as:

$$\overline{T} = (a + w)/2$$

where:

a = age at first reproduction
w = age at last reproduction

9.2.16.1 The community mean generation time is the sum of all generation times for all families collected, divided by the total number of families.

9.2.17 **Metric 11. Proportion of Deformity or Teratogenicity.** Toxicological literature suggests that increased exposure to metals and organic chemical compounds increases the proportion of teratogenicity among fathead minnows (Birge et al., 1985; Simon, 1988). Additional effects have been documented in a recent literature review by Weis and Weis (1989), as well as, exposure to radiation (Lanthrop, personal communication). Teratogenic effects include edematous yolk sacs, post caudal swellings, clear blood, reduced heart beat, lack of fusiform shape, enlarged craniums, square eyes, or improper development of the mandible (Simon, 1988). An increase in deformities or teratogenicity is a result of increased exposure to toxic chemicals or radiation. In reference and complex effluent testing using the fathead minnow embryo-larval survival and teratogenicity test, one very infrequently observed any teratogenicity in control samples. When deformities were observed they were always less than 1% (Simon, personal communication).

9.2.17.1 Improperly preserved specimens will exhibit signs of deformity. Birchfield (1987) determined that cranial anomalies were induced in centrarchids and clupeids by fixing them in low concentrations of formalin (<105), exposing them to high temperatures, or vigorously shaking the fixed specimens. No cranial anomalies were found in larval fish fixed in formalin solutions greater than 10% or in Bouin's fluid.

9.3 Taxonomic Considerations

9.3.1 The ability to differentiate families or larval fishes requires a basic understanding of the morphometric and meristic characteristics which are included in most taxonomic studies (Figures 1 and 2). Extensive literature exists on specific families of larval or larval fishes and alternative measurements, but certain standard measurements and counts continue to be the main ones reported in the literature. The following explanation of how to construct the character in question and the appropriate position to measure or count the character is defined by Simon (1987) and Simon et al. (1987).

9.3.2 Characteristics are subdivided into morphometric, measurable structures, and meristic, countable structures. Standard length and total length are measured from the tip of the snout to the posterior portion of the notochord and to the tip of the caudal finfold, respectively. Morphometric measurements include head length--from the snout to pectoral fin origin; snout length--from tip of the snout to anterior margin of eye; eye diameter--anterior to posterior margin; preanal length--snout to posterior margin of anus; body depth--vertical distance at anus; greatest body depth (also referred to as shoulder depth or head depth)--largest vertical distance (usually anterior dorsal finfold) or measured at origin of pectoral fin; mid-postanal depth--vertical distance measured from dorsal to ventral margin of body at anterior apex of the mean of the postanal myomeres; caudal peduncle depth--vertical distance at anterior apex of penultimate myomere; head width--measured dorsally at the posterior margin of eyes; yolk sac length and depth--measured horizontally and vertically, respectively at the greatest distance on the yolk sac.

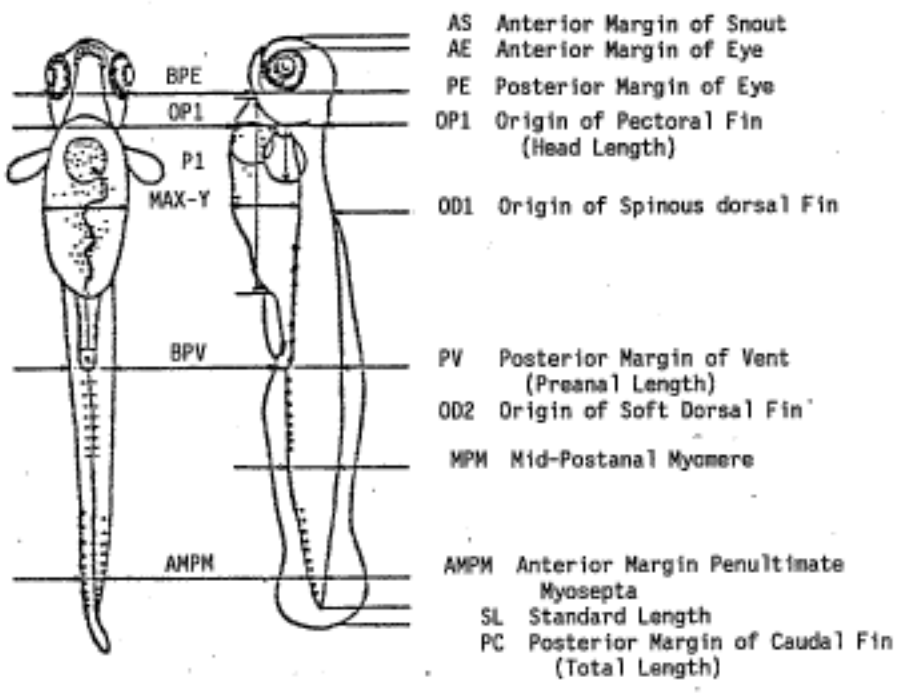

Figure 1. Morphometric characteristics for larval fishes. The yolk sac (Y) is included in width and depth measurements, but fin folds are not. "B" means immediately behind, but not including, the eye or vent. Location of width and depth measures at OD can only be approximated before the dorsal fin begins to form. Fin length is measured along the plane of the fin from the origin to the most distal margin. From Simon et al. (1987).

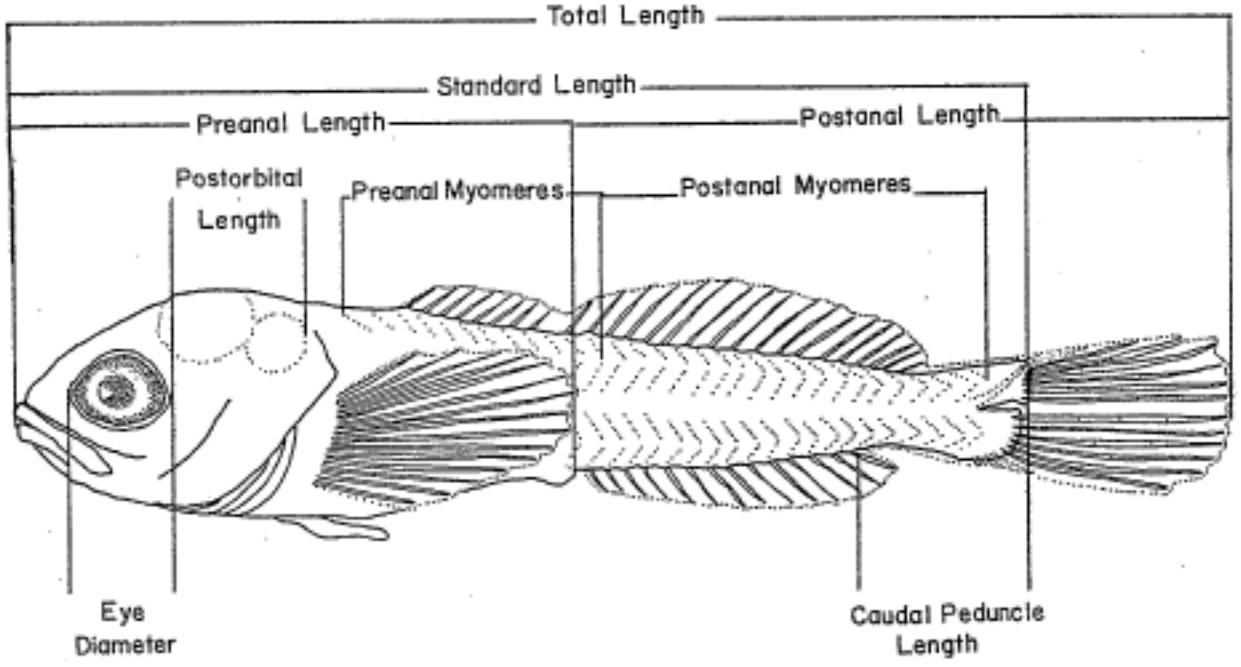

Figure 2. Diagrammatic representation of morphology of a teleost larva. From Auer (1982).

9.3.3 Meristic measurements include the enumeration of all fin rays following methods in Hubbs and Lagler (1958); head canal pores (Hubbs and Cannon, 1935); preanal myomeres--those anterior to a vertical line drawn from the posterior portion of the anus, including those bisected by the line, while postanal myomeres include an urostylar element.

9.4 Provisional Key to the Families of North American Freshwater Fishes

(Adequate information is not available for all early life phases. Families omitted from this key include Amblyopsidae, Cichlidae, Cyprinodontidae, Poeciliidae, Umbridae, Cobitidae, Claridae, Oryziatidaw, and Elassomatidae). Also see Section 12, Fisheries Bibliography, Subsection 12.5.2, Larval and Immature Fishes.

KEY TO THE FAMILIES OF NORTH AMERICAN FRESHWATER FISHES

1a. Body tubular, elongate, eel-like.....2

1b. Body not eel-like; usually with a single gill opening; stomodeum or functional jaws present.....3

2a. Body tubular, elongate, eel-like; seven gill openings; oral sucking disc without jaws; lacking paired fins and distinct eyes.....Petromyzontidae

2b. Body eel-like; usually with a single gill opening; stomodeum, or functional jaws present; eye large; processing paired fins...Anguillidae

3a. Barbels present on chin; mandibular barbels at corners of mouth; usually hatching with some incipient fin rays present; yolk large usually with complex vitellin veins.....Icataluridae

3b. Chin barbels and mandibular barbels absent; if barbels are present limited to ventral portion of snout or single on chin.....4

4a. Adhesive disc present on snout; caudal fin heterocercal.....5

4b. Adhesive disc absent on snout.....6

5a. Adhesive disc papillose; preanal myomeres number x; snout elongate with remnant of adhesive disc until 20 mm total length (TL); dorsal and anal finfolds originating posteriorly, finfold with dark triangular areas near future dorsal, anal, and caudal Fins.....Lepisosteidae

5b. Adhesive disc smooth; preanal myomeres number x; without elongate snout, dorsal finfold originating anterior pectoral fin; gular plate present; body robust.....Amiidae

6a. Larval 10-11 mm TL at hatching; preanal length 60-65% TL; yolk sac large, oval, vascularized; barbels developing on ventral extension of snout; head small.....7

6b. Larvae < 10 mm TL at hatching; preanal length greater than 60-65% TL; large, oil globule; without barbels on ventral surface of snout.....8

7a. Decreasing preanal length at increasing length, 65% TL becomes 60% TL > 11 mm; moderate dorsal finfold originates immediately behind head; dorsal finfold origin length 25% TL; late protolarvae with four barbels; dorsal fin origin posterior to vent; posterior margin of operculum not extending past base of pectoral fin; scutes developing at juvenile stages.....Acipenseridae

7b. Decreasing preanal length at increasing length, 60% TL becomes 50% TL at > 11 mm; dorsal finfold originates at mid-preanal; dorsal finfold origin length 35% TL; late protolarvae with two barbels; dorsal fin origin anterior anus; posterior margin of operculum extending past base or pectoral fin; no scutes developing at juvenile stages.....Polyodontidae

8a. Preanal length greater than 65% TL.....9

8b. Preanal length 60% TL or less.....19

9a. Preanal length greater than 75% TL.....10

9b. Preanal length between 65-75% TL.....13

10a. Preanal length 76-89% TL; total myomeres greater than 45.....12

10b. Preanal length usually less than 75-79% TL; total myomeres less than 45 11

11a. Preanal myomeres > 27; mouth subterminal; body elongate, with usually one to several rows of dorsal pigment.....Catosomidae

11b. Preanal myomeres > ; mouth superior, body elongate usually without pigmentation dorsally.....Clupeidae

12a. Postanal myomeres 13-17; yolk sac small, round and far forward..... .....Osmeridae

12b. Postanal myomeres < 10; yolk sac larger, elongate or oval, situated posteriorly.....Clupeidae

13a. Preanal myomeres greater than or equal to 40.....14

13b. Preanal myomeres less than 40.....15

14a. Postanal myomeres 14015; preanal length 72-75% TL; adipose fin present; swim bladder visibly present.....Osmeridae

14b. Postanal myomeres 15-22; preanal length 67-72% TL; adipose fin absent; swim bladder not visible.....Esocidae

15a. Yolk sac long, bilobed with the anterior portion thick and oval, posterior section thick and tubular, preanal length 58-74% TL.....16

15b. Yolk sac not bilobed, either elongate or oval; if bilobed usually with both sections of equal portion; preanal length 68-75% TL.....17

16a. Larvae densely pigmented, evenly over body, with a dark stripe over gut; usually less than 27 preanal myomeres; body robust.....Cyprinidae

16b. Pigmentation limited to dorsum, usually on cranium and sometimes mid-dorsally in two to four distinct rows; body elongate....Catostomidae

17a. Preanal myomeres < 31, postanal myomeres less than 41.....Catostomidae

17b. Preanal myomeres ≥ 31.....18

18a. Postanal myomeres < 41; larvae large, at 7 mm still possess yolk; preanal length 62-64% TL.....Hiodontidae

18b. Postanal myomeres ≥ 41; preanal length 67-74% TL.....Cyprinidae

19a. Preanal length ≥ 48% TL.....20

19b. Preanal length < 48% TL.....27

20a. Preanal ≥ 56% TL.....21

20b. Preanal 48-55% TL.....23

21a. Preanal myomeres < 26; preanal length 56-58% TL; larvae large, yolk sac present until 7-10mm TL.....Hiodontidae

21b. Preanal myomeres < 26; preanal length < 56% TL; yolk sac larvae < 7 mm TL.....22

22a. Preanal myomeres 8-12; postanal myomeres 9-15.....Moronidae

22b. Preanal myomeres 15-26; postanal myomeres 18-26.....Percidae

23a. Preanal myomeres ≥ 15.....Percidae

23b. Preanal myomeres < 15.....24

24a. Total myomeres ≤ 26.....Moronidae

24b. Total myomeres > 26.....25

25a. Preanal myomeres 14-16; preanal length > 50% TL.....Gasterosteidae

25b. Preanal myomeres <.....26

26a. Postanal myomeres < 19; gut massive, uncoiled; pectoral fins proportional.....Centrarchidae

26b. Postanal myomeres ≥ 19; large pectoral fins.....27

27a. Preanal length < 35%; preanal myomeres 6-7; postanal myomeres 28-31.....Atherinidae

27b. Preanal length > 35%.....28

28a. Postanal myomeres approximately 40; preanal length 39-44% TL.....Gadidae

28b. Postanal myomeres much less than 40; preanal length 44% TL.....29

29a. Postanal myomeres ≤ 11; posterior oil globule in yolk sac.....30

29b. Postanal myomeres > 20; mouth terminal to superior; preanal length 45% TL.....30

30a. Postanal myomeres > 30; mouth terminal to superior; preanal length 45% TL.....Fundulidae

30b. Postanal myomeres < 20; mouth subterminal to inferior; preanal length 45% TL.....Percopsidae

9.5 Fish Larvae Sampling Precision

9.5.1 When investigators collect larval fish samples, the accuracy of the sampling methods and equipment must be carefully considered. Using literature data, Cyr et al. (1992) demonstrated that past sampling designs have been inadequate for the comparison of larval fish abundance across sites or time periods. Therefore, Cyr et al. (1992) developed a general model based on published data to predict the variance in larval fish abundance among replicate samples and provided guidelines for estimating the number of larval fish samples necessary to obtain acceptable or desired levels of precision at a collecting site. For studies that include large aquatic habitats of many sites as well as changes in abundance through time, they concluded that investigators must consider patterns of spatial and temporal variation when sampling larval fish populations. They also indicated that in arriving at an efficient allocation of sampling effort, that each scale of variation must be considered. Furthermore, careful consideration of precision in the context of data quality objectives (DQOs) (See Section 2, Quality Assurance and Quality Control) will improve the qualitative or quantitative evaluations of ichthyoplanktonic population studies.

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